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Species diversity of ants in karst limestone habitats in Bukidnon and Davao Oriental, Mindanao, Philippines

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Abstract. The Philippines has high diversity of ants but many species are still undescribed. In this study, species diversity of ants was determined in karst limestone habitats in selected areas in Davao Oriental, Kitaotao, Bukidnon and Valencia City, Bukidnon using a combination of quadrat, hand collection, and pitfall trapping methods. Results showed moderate species diversity in the sampling sites. Twenty three ant species were recorded and *Crematogaster* sp. was the highest in relative abundance. Cave I in Kitaotao, Bukidnon and Cave 1 in Davao Oriental had high species richness. Ordination analysis showed that ants from the caves in Davao Oriental were the most uncommon among the cave sites. *Paratrechina longicornis*, an invasive ant species was found only in Davao cave I. The presence of five opportunist ant species in all caves except Davao cave II indicates high degree of habitat disturbance. Vegetation, leaf litter depth, and disturbance were the factors observed affecting ant species diversity. More surveys in karst limestone areas are needed to have a complete database of the species of ants present in Mindanao.
Key Words: *Crematogaster* sp., invasive, opportunist species, *Paratrechina longicornis*.

Introduction. Ants are important in terms of biodiversity as they are the most diverse, abundant and ecologically significant organisms on earth (Wilkie et al 2010). Their role in the environment varies with respect to disturbances and habitat modification like farming, clear-cutting, and mining (Wang et al 2001). Species able to tolerate disturbed habitats have to be adapted to highly modified environments (Rizali et al 2013). Majer et al (2007) concluded in their study that ants perform moderately well as environmental indicators and extremely well as biodiversity indicators.

Ants are the most successful social animals on earth which often form complex colonies in nature (La Salle & Gauld 1993). They give support to many organisms by providing stable food resources and numerous niches (Lachaud & Pérez-Lachaud 2012). Their morphology as well as their habitat preference vary and their range of life ways is enormous (Bolton 1994).

The Philippines has a total estimated number of around 1,000 species of ants from which only 394 ant species are known. About 215 species of ants and 40 unknown species were recorded in Mt. Isarog, Philippines (Alpert & General 2011). Batucan & Nuñeza (2013) documented 14 species of ants in the caves of Siargao Island Protected Landscape and Seascape, Surigao del Sur.

Limestone karsts are “arks” of biodiversity and often contain high levels of endemism and are excellent areas to collect ants (Clements et al 2006). However, an overview of the current status of karst protection in the Philippines presented by Restificar et al (2006) showed that of the 35,000 square kilometers of karsts landscape in the country, about 29% are protected, and the remaining 71% are at risk.

The Philippines’ high rate of habitat destruction particularly in limestone areas is alarming. An evaluation of the status of ants in these areas is crucial. Since ant diversity in Mindanao particularly the limestone habitat is not fully documented, this study was conducted to identify the ant species, determine ant diversity and abundance in selected limestone habitats of the provinces of Davao Oriental and Bukidnon and the city of Valencia in the Philippines.

Material and Method. Ants were collected for 21 sampling days from April to May, 2010 in the karst limestone habitats in Barangay Concepcion, Valencia City, Bukidnon; Barangay. Poblacion, Kitaotao, Bukidnon; and Barangay Limot, Taraggona, Davao Oriental (Figure 1).

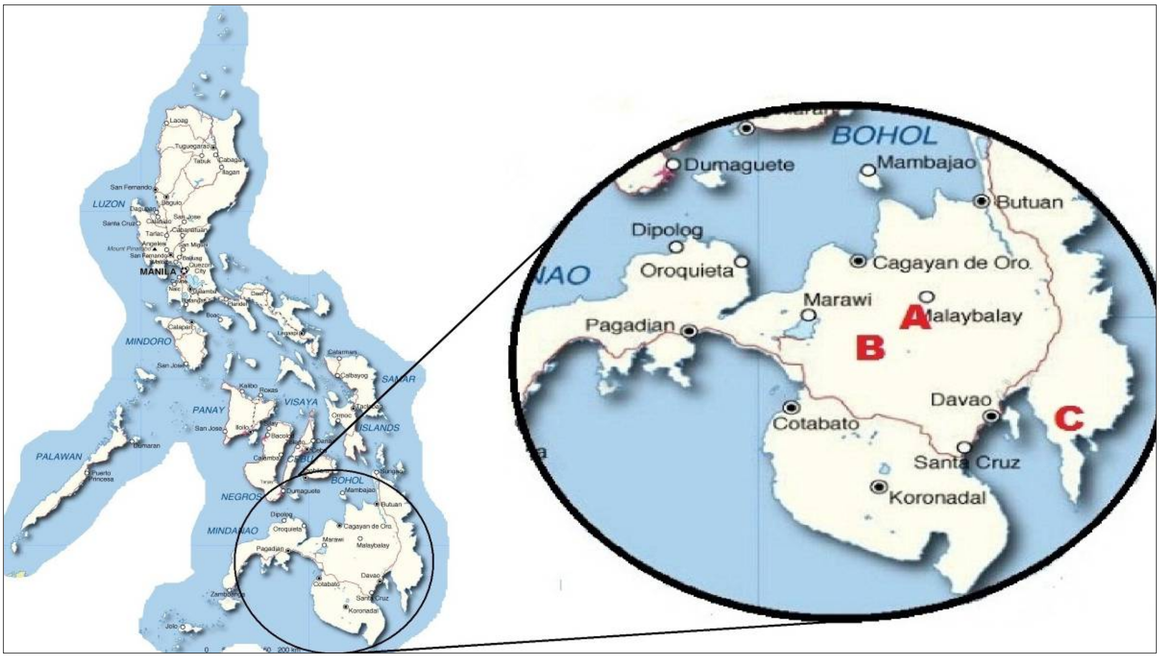

Figure 1. Sampling sites: A) represents Valencia City, Bukidnon; B) represents Kitaotao, Bukidnon; C) represents Tarragona, Davao Oriental (http://resorts-hotels-philippines.lejinternetplaza.com/hotels-resorts/Information/Map_Philippines.php).

Description of sampling sites

Sampling area 1 - was in Barangay Concepcion, Valencia City, Bukidnon. It is bounded on the North by the Municipality of Lantapan and Malaybalay City. The Municipalities of Maramag and Quezon lie in the south and the Municipalities of Pangantucan and Talacag in the East. Two sampling sites were established: Salawao Cave (Cave Site I) and the Kariis Cave (Cave Site II). Salawao (720 meters above sea level) and Kariis cave (437 meters above sea level) have coordinates of 07º42'062" North, 125º03'249" East. The nearest accessible road is one kilometer away and can be reached by a four-wheeled vehicle. Water is flowing in both caves. People use to visit the area to bathe or do spelunking. The main entrance of Salawao Cave, about three meters in diameter was partially illuminated. The ground was moderately covered by wet leaf litter. The Kariis Cave entrance is about three meters in diameter and fully illuminated. The sampling area was surrounded by trees.

Sampling area 2 - was in Barangay Poblacion, Kitaotao, Bukidnon. Kitaotao is one of the municipalities in the Third Congressional district in Bukidnon. Situated in the southern part of Bukidnon, Kitaotao is bounded in the north by the municipalities of Don Carlos, Quezon and San Fernando; in the west by the municipality of Kadingilan, Dangcagan and Kibawe; in the south by the Province of North Cotabato and in the east by the Province of Davao del Norte. It is 38 kilometers away from the first sampling area. Three caves were selected as sampling sites. Cave 1 (Cave Site III) has three openings with grid coordinates of 07º42'062" North, 125º03'249" East with an elevation ranging from 316-328 meters above sea level (masl). The three openings were partially to fully illuminated, ranging from 1-5 m in diameter. The cave main opening has dry soil surface but muddy in the inner recess area. The area is surrounded by trees. The ground had totally dry litter. The leaf-litter depth was high at approximately 125 mm. Cave 2 (Cave Site IV) has grid coordinates of 07º42'062" North, 125º03'249" East with an elevation of 325 masl. Cave 2 is about 250m from Cave 1. It has one opening for entrance and another for exit. The entrance is partially illuminated and measured only about one meter in diameter. The area is surrounded by trees. The ground had moderately wet leaf-litter. The leaf-litter depth on the ground was low at approximately 45 mm. Cave 3 (Cave Site V) has three openings and has grid coordinates of 07°38'628''-07°38'685'' North, 125°01'929''-125°01'969''East. The elevation ranges from 315-353 masl with partially illuminated entrance. The size of the entrance ranges from 2-4 meters in diameters. Stagnant water is present at some cave entrance and also inside the cave due to a flood. The ground had partially wet leaf-litter. The leaf-litter depth was high (100 mm).

Sampling area 3 - is in Barangay Limot, Tarragona, Davao Oriental. Tarragona is a 4th class municipality in the province of Davao Oriental that lies 205.84 kilometers in the north-eastern part of Mati. It is 311 kilometers away from the second sampling area. Tarragona is bounded in the northwest by the municipality of Lupon, Municipality of Manay in the North, the Philippine Sea in the east, Mayo Bay of Mati in the South and the Municipality of Mati in the Southwest. Two caves were selected as sampling sites. The caves have dense canopy cover located at the mountainside and were less than five km from the road accessible by four-wheeled vehicle. The two caves were located at coordinates 07°01'719" North, 126°16'984" East with an elevation of 370-470 masl. Cave entrances were partially illuminated and measured about 1 m in diameter. The two caves are surrounded by trees and other plants. The ground of the two cave entrances had partially wet leaf-litter. The leaf-litter depth on the ground was high (110 mm) in Davao cave I and low (40 mm) in Davao cave II.

Ant collection was done using the quadrat, hand collection, and pitfall trapping methods. Three quadrats with 1 x 1 meter each were established inside the cave and another three quadrats outside. Ants within the quadrats were observed, counted and collected. Ants found beyond the quadrats and within the caves were also collected. The collected ants were placed immediately into vials with 70% ethyl alcohol.

Vials about 3 inches in length were used as pitfalls traps. The vials were buried up to the rim in the soil. A killing agent, 70% ethanol, was added in the vials to capture crawling ants. The set-up was placed in every quadrat in each cave. This method was used to estimate the abundance and species composition of ground surface-active ants (Greenslade 1973).

The ants collected were sent to the Philippine National Museum for identification by an expert on ant taxonomy. Biodiversity indices were determined using Biodive Pro and an ordination diagram was made using SPSS Version 17.

Results and Discussion. Table 1 shows 23 species of ants belonging to six functional groups. Andersen (2011) reported that ant functional group analysis is based on global–scale responses of ants to environmental stress and disturbance operating at the genus or sub-species level. Six species in the areas sampled belong to Subordinate Camponotini. Ants of Subordinate Camponotini are generally large in size and often forage at night to reduce interaction with other ant groups (Andersen 2011). Five species belong to Opportunist functional group. Andersen & Majer (2004) stated that opportunist species predominate only in environments experiencing high levels of stress and disturbance. All the caves in this study have opportunist species except Davao cave II. The presence of opportunist species suggests that all the caves except Cave II of Davao may be exposed to high degree of stress and disturbance. Four species are specialist predators and other four species are tropical climate specialists. The generalized myrmicinae and cryptic species groups have two species each. Andersen & Majer (2004) reported that cryptic species and specialist predators are especially sensitive with their abundance typically declining with increased disturbance.

Table 1

Data showing the species of ants present in the caves and the functional group

Species name	*Functional group*	*Davao cave I*	*Davao cave II*	*Kariis cave*	*Salawao cave*	*Kitaotao cave I*	*Kitaotao cave II*	*Kitaotao cave III*	*TOTAL*
Subfamily Dolichoderinae									
Dolichoderus thoracicus	Tropical Climate Specialist	-	-	+	+	+	+	+	5
Tapinoma sp.	Opportunist	-	-	+	-	-	-	-	1
Technomyrmex albipes	Opportunist	-	-	-	-	+	-	-	1
Subfamily Formicinae									
Echinopla vermiculata	Subordinate Camponotini	-	-	-	+	-	-	-	1
Gnamptogenys sp.	Tropical Climate Specialist	-	-	-	-	+	-	+	2
Leptogenys sp.	Specialist Predators	+	-	-	-	-	-	-	1
Paratrechina longicornis	Opportunist	+	-	-	-	-	-		1
Polyrachis hector	Subordinate Camponotini	+	-	-	-	+	-	+	3
Polyrachis mindanaensis	Subordinate Camponotini	+	-	-	-	+	+	+	4
Polyrachis illaudata	Subordinate Camponotini	-	+	-	-	-	-	-	1
Polyrachis sp.	Subordinate Camponotini	+	-	-	+	-	-	-	2
Polyrachis olybria	Subordinate Camponotini	-	+	-	-	-	-	-	1
Tetramorium sp.	Opportunist	-	-	+	+	+	+	+	5
Subfamily Myrmicinae									
Crematogaster sp.	Generalized Myrmicinae	+	+	-	-	+	+	+	5
Monomorium sp.	Generalized Myrmicinae	+	-	-	-	-	-		1
Myrmicaria brunnea	Opportunist	+	-	-	-	+	-	-	2
Pheidologeton maccus	Tropical Climate Specialist	-	-	-	-	+	+	+	3
Pheidologeton sp.	Tropical Climate Specialist	-	-	+	+	-	-	-	2
Subfamily Ponerinae									
Odontomachus sp.	Specialist Predators	-	-	-	-	+	+	+	3
Odontoponera sp.	Cryptic species	+	-	-	-	-	-	-	1
Pachycondyla obscurans	Specialist Predators	+	+	-	-	-	-	-	2
Pachycondyla sp.	Specialist Predators	-	-	-	+	-	-	-	1
Platythyrea parallela	Cryptic species	-	+	-	-	-	-	-	1
TOTAL		10	5	4	6	10	6	8	

The ant species collected belong to subfamilies Dolichoderinae, Formicinae, Myrmicinae and Ponerinae. Subfamily Formicinae had the most large number of ant species (Figure 2). Most species belonging to subfamily Formicinae are arboreal ants, an example is the species belonging to genus *Polyrhachis* (Watanasit et al 2003). Moffett (2012) reported that shared recognition cues of ants provide clear criteria for defining colonies. Further surveys are necessary to establish whether the present ant community dominated by Formicinae is a general characteristic of karst areas in Mindanao.

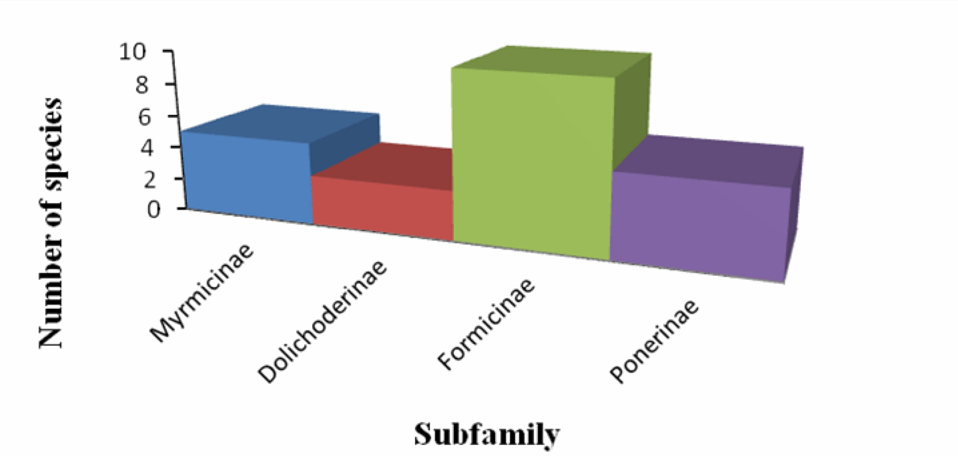

Figure 2. The subfamily with the most number of ant species collected.

Crematogaster sp. had the highest relative abundance in the karst areas (Figure 3). As a species commonly found in disturbed habitats (Torchote et al 2010) and an arboreal ant, the vegetation present in limestone areas may have contributed to the abundance of *Crematogaster* sp. Raimundo et al (2004) reported that a high density of trees in the immediate vicinity of a given diaspore probably increases the probability of interaction with arboreal ants. *Crematogaster* sp. was also one of the species present in the caves of Texas (Cokendolpher et al 2009).

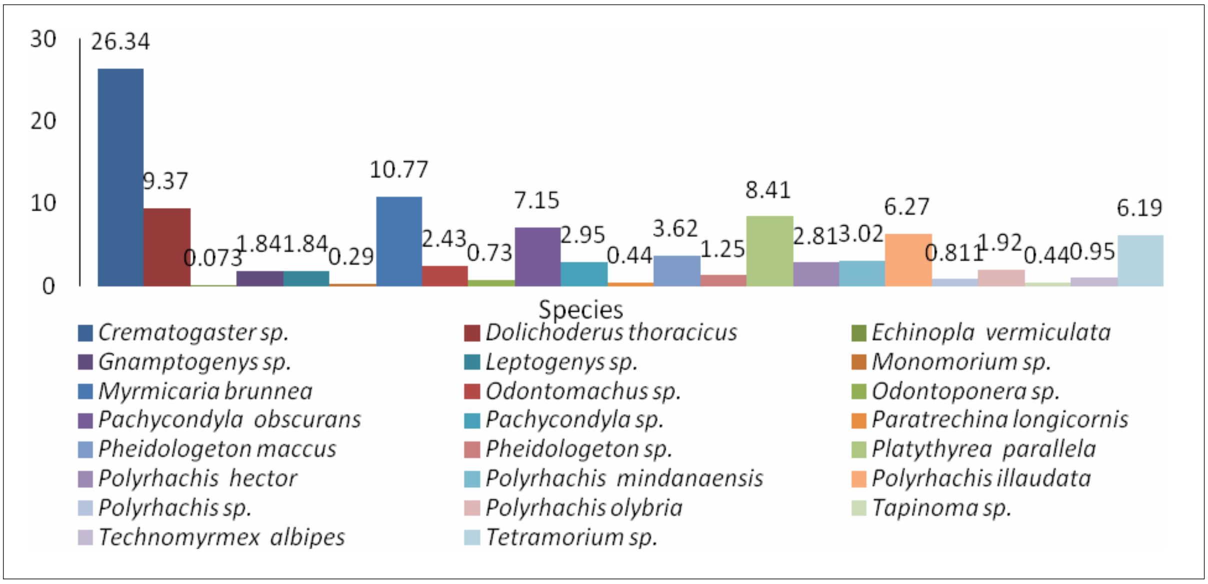

Figure 3. Total relative abundance of the collected species of ants.

The species with the lowest abundance was *Echinopla vermiculata* which may be due to the foraging activity of the species. Daily and seasonal foraging activity of ants is mainly modulated by the interaction of abiotic and biotic variables. Foraging activities of ants species are determined by physical variables which is modulated by biotic variables such as interspecific competition, the habitat structure, productivity of resource, different food type, colony needs and other physiological constraints such as heat tolerance (Paris & Espadaler 2012). CSIRO (2011) reported that *Echinopla* species' nest and foraging areas are not readily accessible since *Echinopla* species are found well above the ground. Individuals of the species may not have been easily encountered during the course of the sampling for this reason.

Table 2 shows that all the caves are moderately diverse (H' = 2.546). Kitaotao Cave 1 had the highest diversity of ant species. Salawao Cave had the lowest diversity among all the caves (H' = 1.187). Stress caused by human disturbance in this cave may have been a limiting factor for most species as Graham et al (2004) found that highly disturbed areas had fewer species and greater number of ants than those with lightly or moderately disturbed areas. Savitha et al (2008) also reported that disturbed sites have more number of common species.

Table 2

Data showing the biodiversity indices

	Davao cave I	*Davao cave II*	*Kariis cave*	*Salawao cave*	*Kitaotao cave 1*	*Kitaotao cave 2*	*Kitaotao cave 3*	*All caves*
Elevation (masl)	370	470	437	720	316-328	325	315-353	
Species	10	5	4	6	10	6	8	23
Individuals	236	268	43	94	259	133	322	1355
Dominance	0.2267	0.3075	0.3056	0.3594	0.1845	0.37	0.3847	0.1157
Shannon-Weiner	1.796	1.335	1.276	1.187	1.977	1.276	1.36	2.546
Evenness	0.6025	0.7598	0.8954	0.5464	0.7223	0.5968	0.4868	0.5544

The dominance values were found to be low indicating the absence of dominant species of ants in the areas sampled. The vegetation is enough to support ants indicating no competition for resources since plants supply food to ants. Heil (2010) reported that ants indirectly defend plants against herbivores and function in dispersal through transporting seeds. On the other hand, plants provide food resources or nesting space in order to increase their presence and capacity to function as defenders. Each species of ants appears in a segregate manner on activities like the gathering of their food.

A more or less even distribution of ant species was observed except for Kitaotao cave 3. The previous flood might have affected the distribution of ant species in Kitaotao cave 3. Mertl et al (2009) stated that the degree of flooding had the strongest impact on ant density in a flooded forest. The reduction of suitable nesting sites caused a linear decrease in ant abundance.

Kitaotao caves were closely related in terms of distribution and abundance of ant species (Figure 4). This may be due to the presence of almost the same vegetation since all these caves were at the same sampling area. However, the differences in the leaf-litter cover thickness affect the diversity of each cave. Silva et al (2011) concluded that ant species density increased with increasing number of leaves and number of leaf morphotypes, but also influenced by plot location factors such as plant species richness, vegetation structure and environmental conditions. These caves have almost the same species. *Technomyrmex albipes* which was only found in Kitaotao cave I is known to be associated with humans. The presence of a nearby residential area explains the presence of this ant. *T. albipes* or the White-footed Ants (WFA) is considered a nuisance pest by homeowners because it is frequently observed in kitchens, bathrooms and the exterior building (Warner et al 2005). This ant is known to play a major role in the spreading of the pineapple wilt disease (Sulaiman 1997).

Salawao and Kariis caves were closely related in terms of distribution and abundance of ant species which is probably due to the shared presence of stress caused by human activity in both caves. However, Salawao cave has two species, *Echinopla vermiculata* and *Pachycondyla* sp. that are found only in this cave. The presence of the two species may be due to higher elevation of Salawao cave (720 masl) than other caves that were sampled. Bharti et al (2013) and Sanders et al (2003) observed that ant species richness increased linearly with an initial increase in elevation and peaked at mid-elevation and thereafter decreased, thus forming a mid-elevation peak. In addition, *Echinopla* species are arboreal ants which nest on dead twigs, vines or branches on trees (CSIRO 2011). In result, they are seldom collected unless especially sought. A species of the same genus, *Echinopla australis* nests in hollow twigs of rain forest canopy (Taylor 1992). The presence of trees and plants near the entrance of Salawao cave plus its exposure to sunlight might be a favorable condition for the species. Savitha et al (2008) reported that canopy and litter in the habitats support and increase ant diversity. *Pachycondyla* species is diverse in its morphology and behavior (Wild 2002). A species of the same genus, *Pachycondyla sennaarensis*, a stinging ant is the most common ant in the savannah regions and is spreading rapidly into human settlements (Paknia 2006).

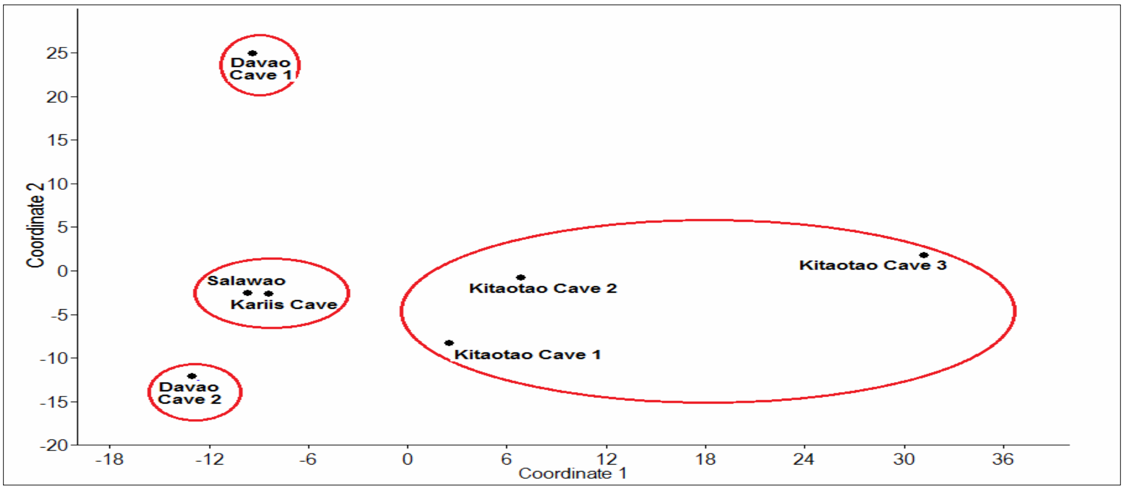

Figure 4. An ordination diagram showing the similarities in caves.

Davao caves have species that are mostly uncommon among all caves. This is because both caves are less disturbed and less disturbed areas can support more ant species than highly disturbed ones. However, only two species were found similar in both caves thus making them most likely unrelated. Difference in diversity between the two caves may be due to higher elevation with steep slopes in Davao cave 2. Higher elevations with steep slopes and strong winds would not permit litter accumulation which results to decreased abundance and species richness of ants (Sabu et al 2008)

Paratrechina longicornis was found in Davao cave 1, the cave that ranks second in terms of ant diversity. *P. longicornis* also called longhorn crazy ant is invasive (Harris & Abbott 2002) and one of the widespread tramp ants which is a household, garden and significant agricultural pest (Wetterer 2008). It is said to be a disturbance specialist and is seemingly absent from undisturbed and intact natural habitats (Harris & Abbot 2002) but it can be very common in disturbed and semi-natural environments (Wetterer 2008). Wetterer et al (1999) reported that in Biosphere 2, an artificial biome constructed in Arizona, *P. longicornis* became the dominant ant species within approximately two years of first detection. *P. longicornis* has been reported to be associated with humans as it occurs and known to be found in large numbers in homes or out-of-doors and with this, there is no limit to the latitude where this species can exist (Nickerson & Barbara 2000). *P. longicornis* in Davao cave 1 may have been accidentally transported by climbers and spelunkers that visit the area.

The presence of pest and invasive species of ants in Kitaotao cave 1 and Davao cave 1 which have high diversity is an area of concern since invasive species are known to dominate and displace the native species. The presence of pest and invasive ants indicates disturbance caused by habitat change.

Conclusion and Recommendation. Caves of Davao Oriental showed the most uncommon assemblage of ant species and is attributed to being less disturbed than the other areas. *Paratrechina longicornis* an invasive ant species found only in Davao cave 1 may have been transported by climbers and spelunkers. The presence of invasive and opportunist ant species in most caves indicates that the caves where they are found are exposed to high levels of stress and disturbance. It is recommended that more surveys be conducted in Mindanao to fully come up with a complete database on the species richness of ants as well as better understand the ecology of ants in karst limestone habitats. The description of undescribed species in this study may increase the total number of ant species in karst limestone areas in Mindanao.

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